

Use of WIM Data in Development of a Stochastic Flow Model for Highway Bridge Design

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What is Statistical Convolution And Why Should We Use It?

- **Convolution of the distribution gross weight with the likelihood of having n vehicles on the span at a point in time**
- **Use it because of the huge computational effort required for code calibration and structural assessment when using WIM data**

Development of Model

- Single Lane:

$$P(N = n) = P\left(\sum_{i=1}^{n+1} \Delta T_i > \frac{L}{V} \geq \sum_{i=1}^n \Delta T_i\right) = \\ \Gamma_{n,1}\left(\mu\left(\frac{L}{V} - nt_0\right)\right) - \Gamma_{n+1,1}\left(\mu\left(\frac{L}{V} - (n+1)t_0\right)\right)$$

$\Delta T = \text{Headway/S speed}$

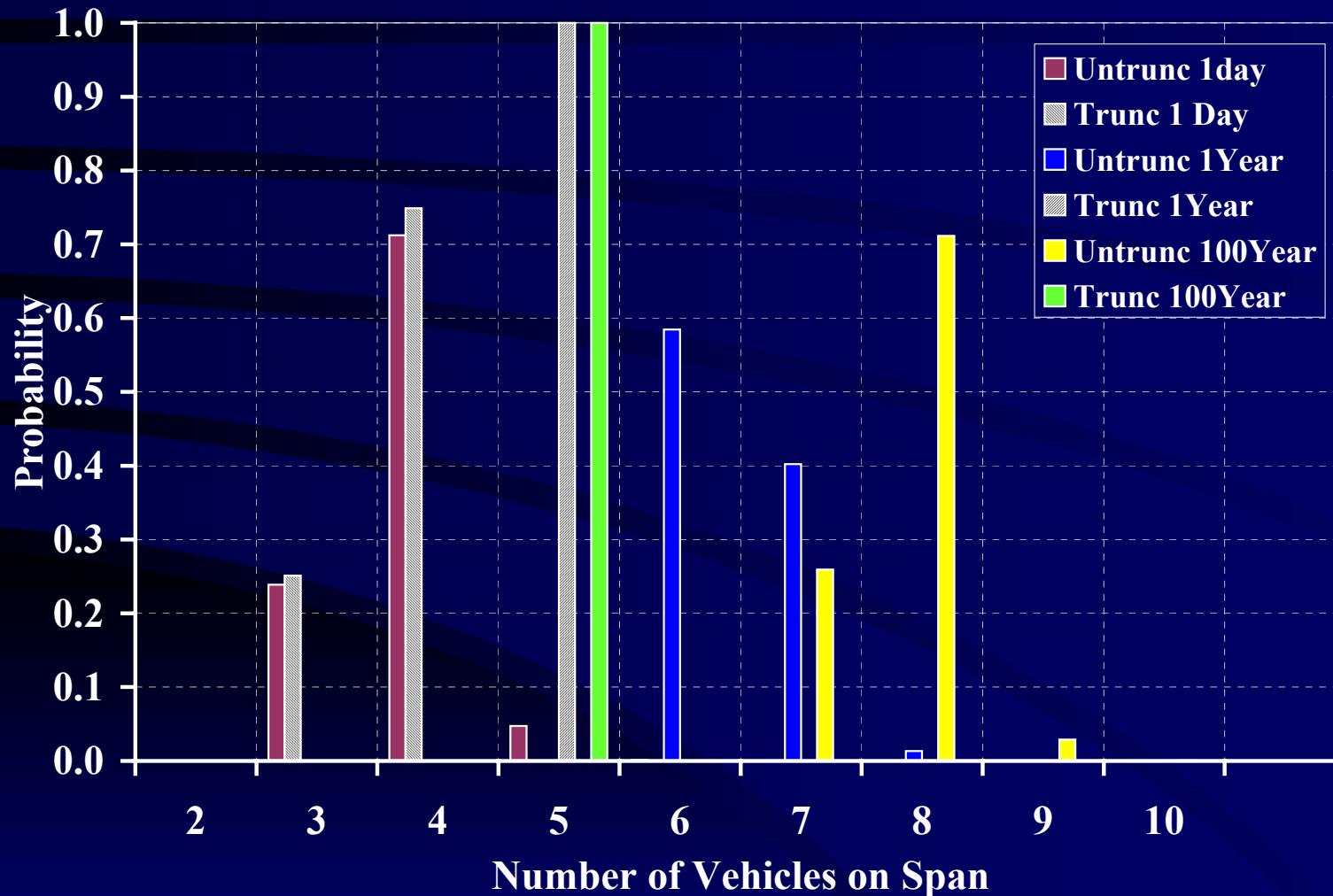
L/V is the bridge crossing time

$t_0 = d_0/V$ Distribution is truncated to avoid overlapping

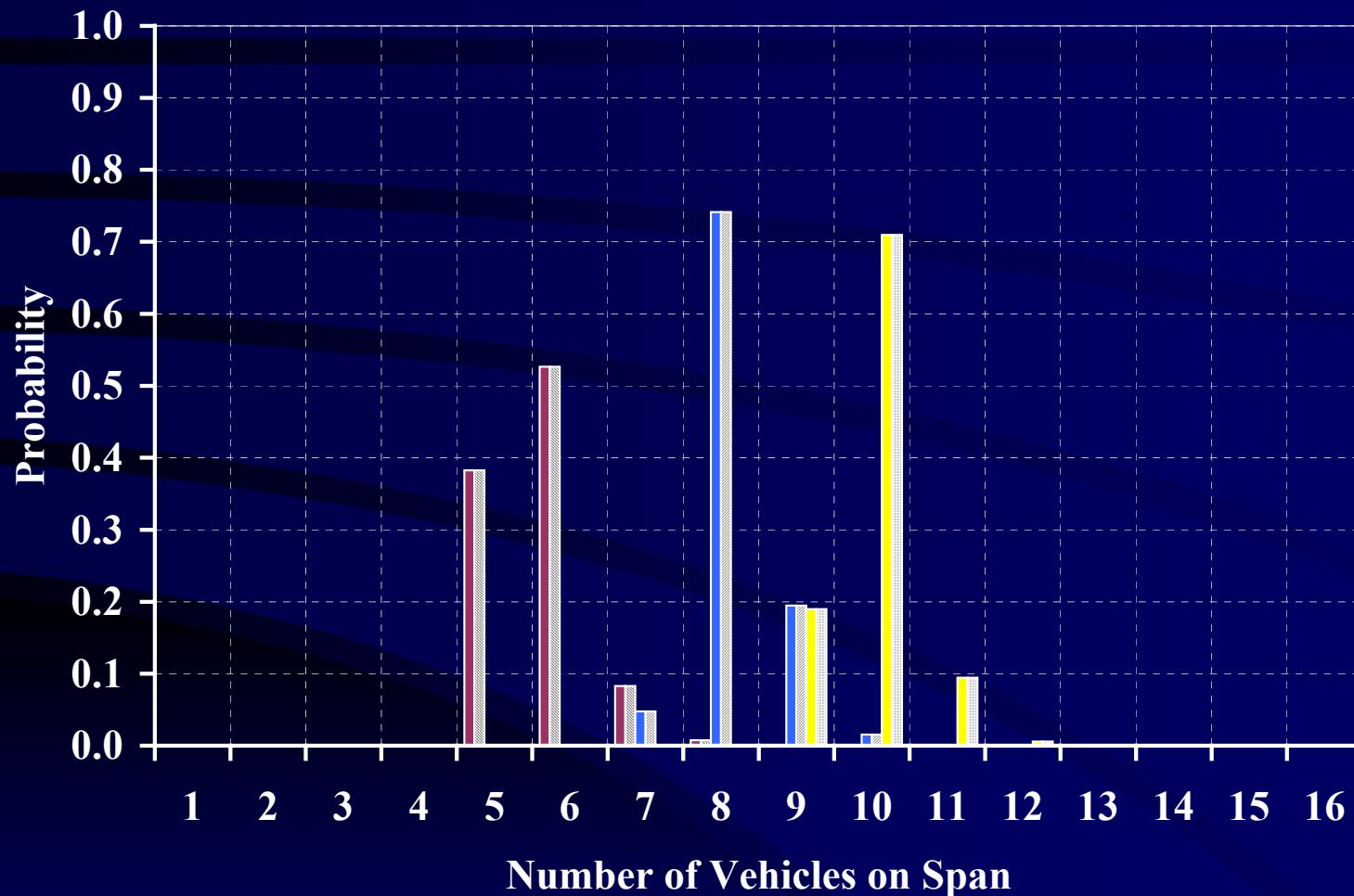
$$\mu = \phi / (1 - \phi t_0)$$

ϕ is the number of vehicles per hour

- Single Lane 50m Span

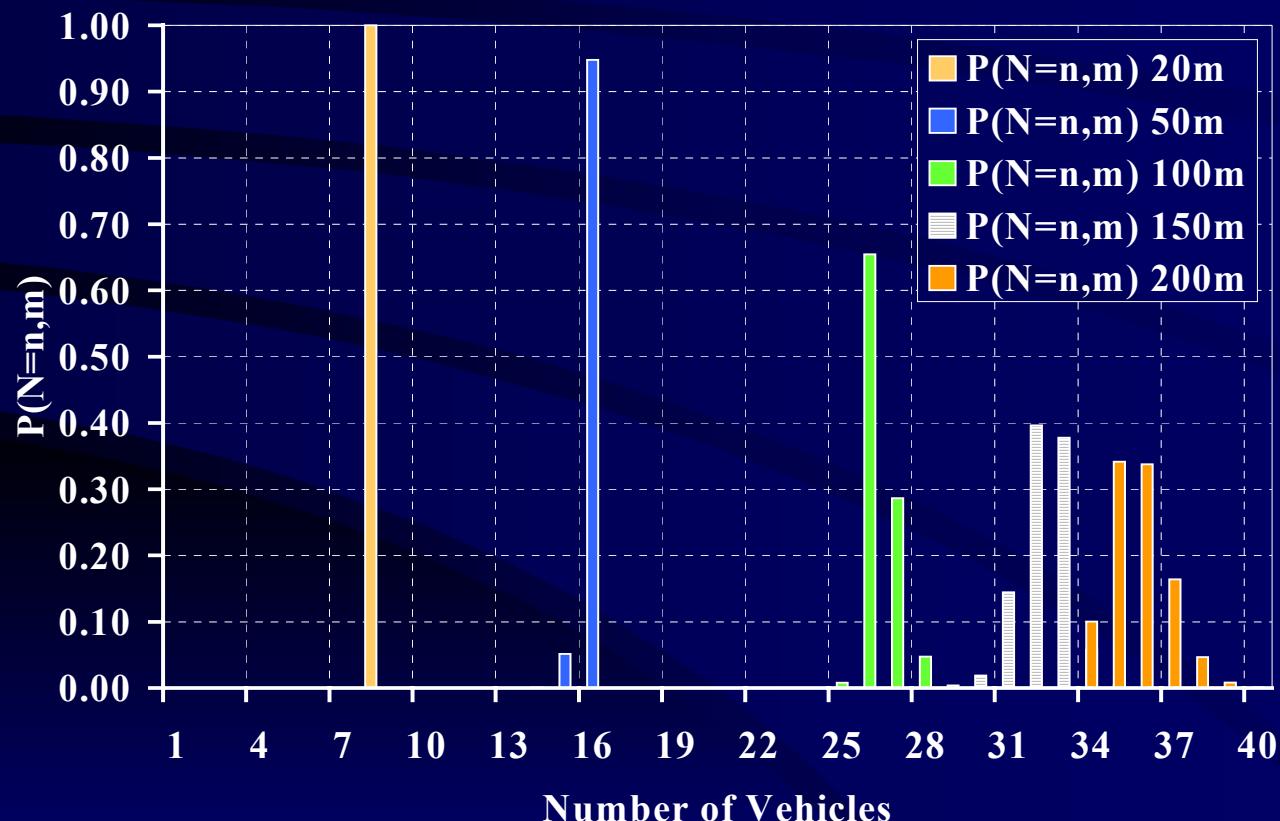


- Single Lane 200m Span



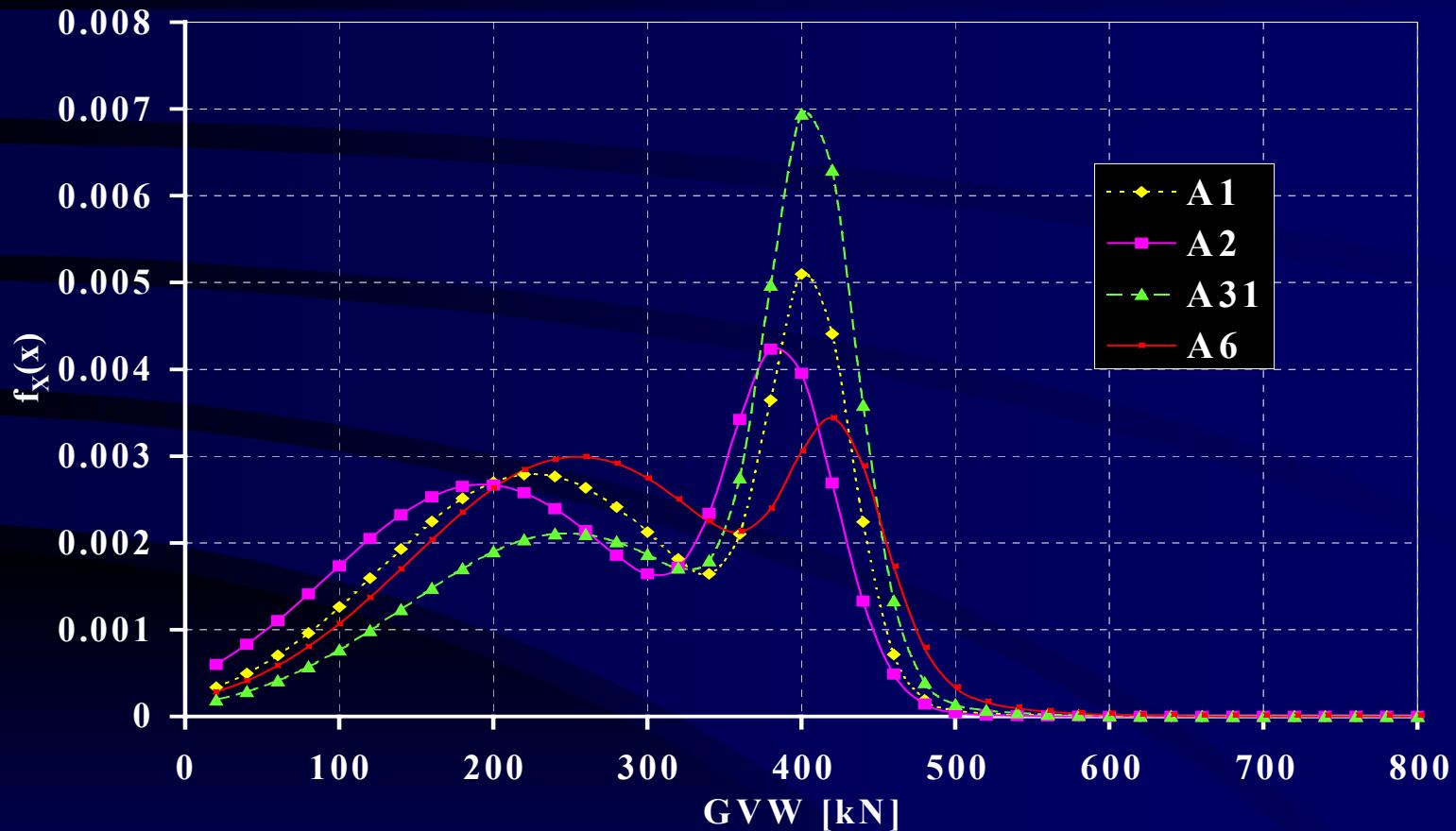
- Multiple Lane, 4 Lanes :

$$P(N = n, m) = \sum_{i=0}^n P(N = i, m - l).P(N = n - i, l)$$



- **GVW Distribution**

$$f_W(x) = \rho_1 f_{N(m_1, \sigma_1)} + \rho_2 f_{N(m_2, \sigma_2)}$$



- Convolution Model

$$f_Q(x) = \delta_0 + \sum_{n>0} P(N=n) \cdot f_W^{*n}(x)$$

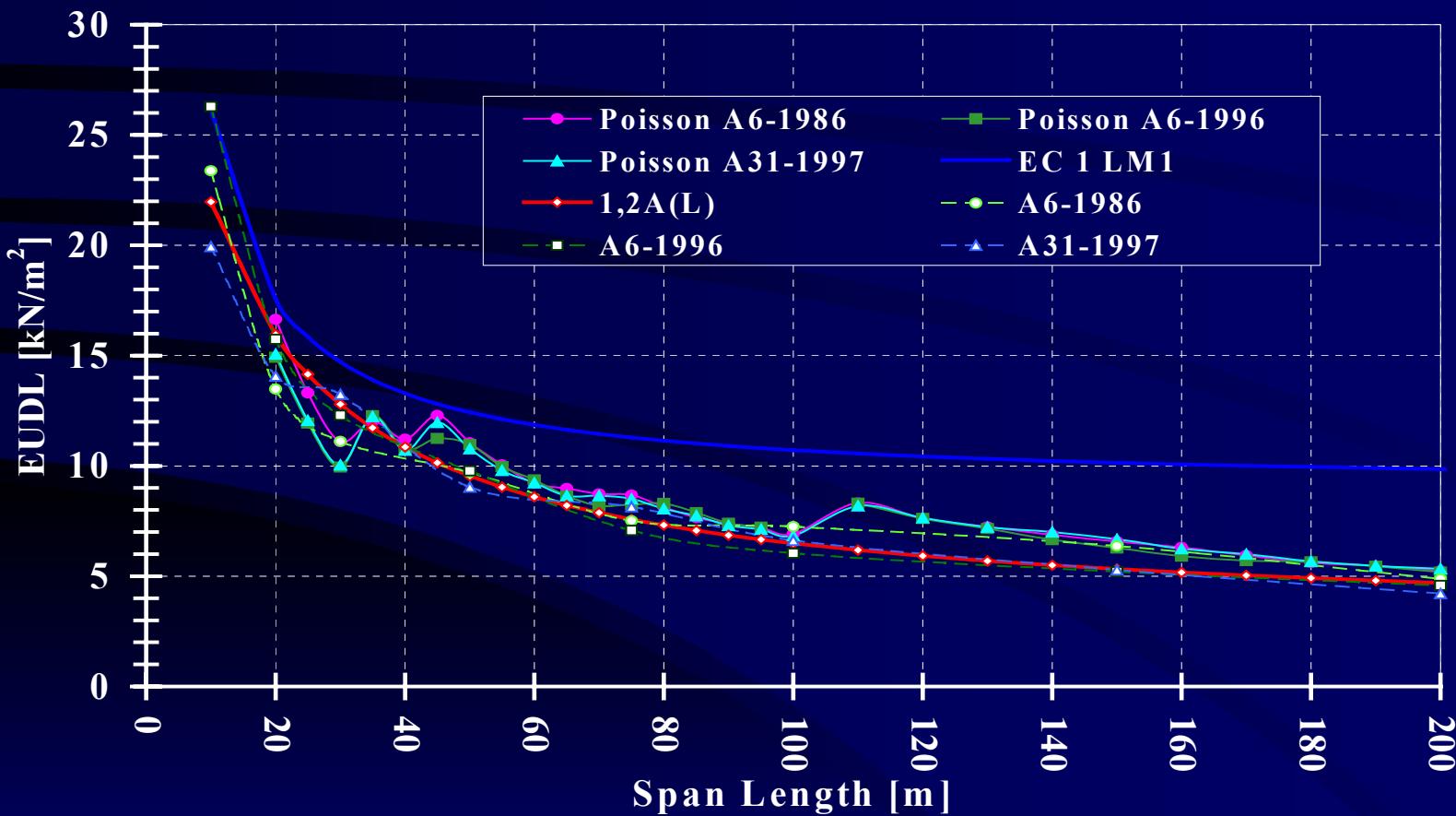
$$f_W^{*n}(x) = \sum_{i=0}^n C_n^i p_1^i (1-p_2)^{(n-i)} \varPhi(m_{in}, \sigma_{in}, x)$$

$$m_{in} = i m_1 + (n-i) m_2$$

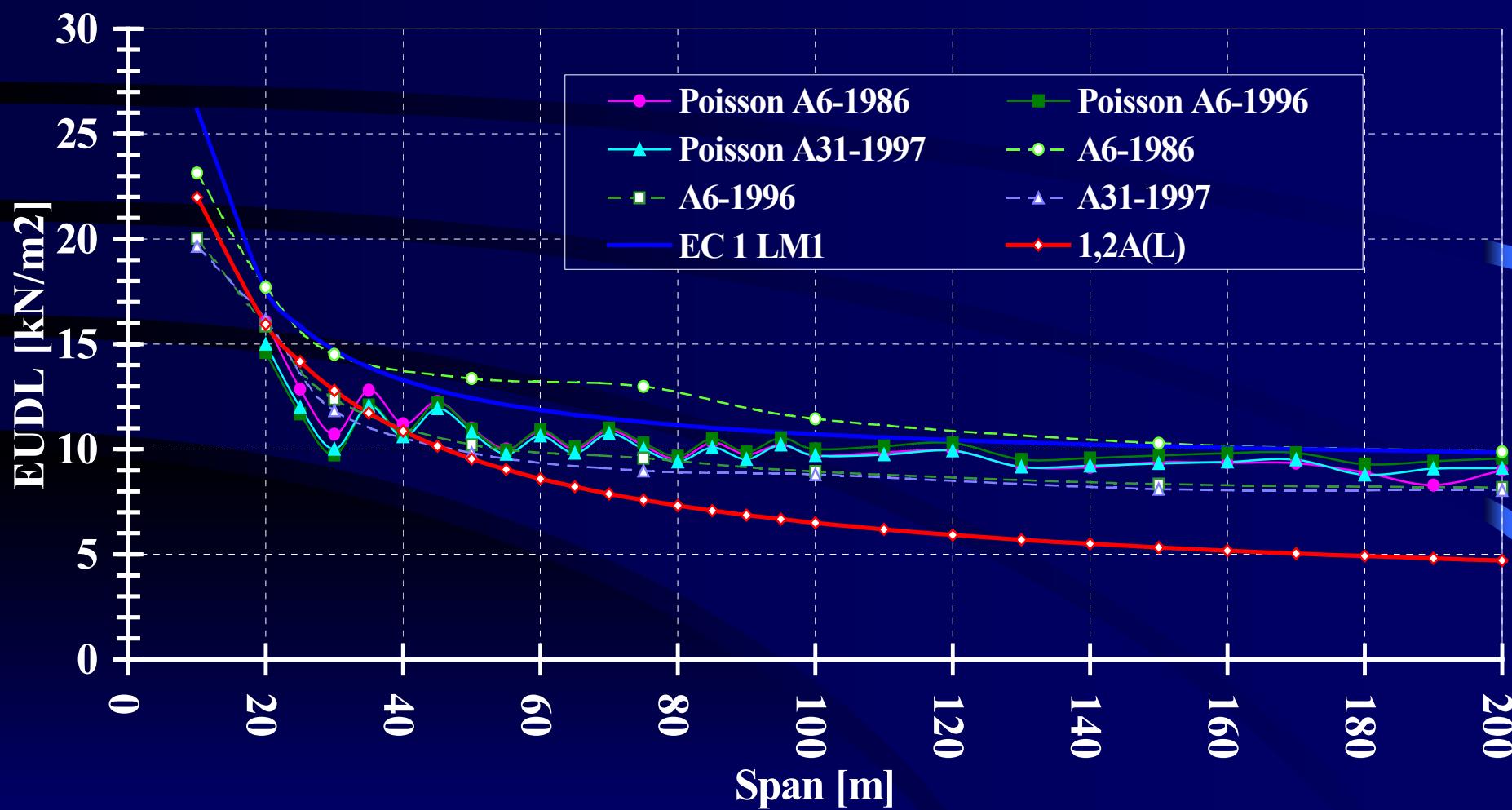
$$\sigma_{in}^2 = i \sigma_1^2 + (n-i) \sigma_2^2$$

$$G_Q(q) = \sum_{n>0} P(N=n) \sum_{i=1}^n C_n^i (1-p_2)^{n-i} p_1^i g_{N(0,1)}\left[\frac{x-m_{ni}}{\sigma_{ni}}\right]$$

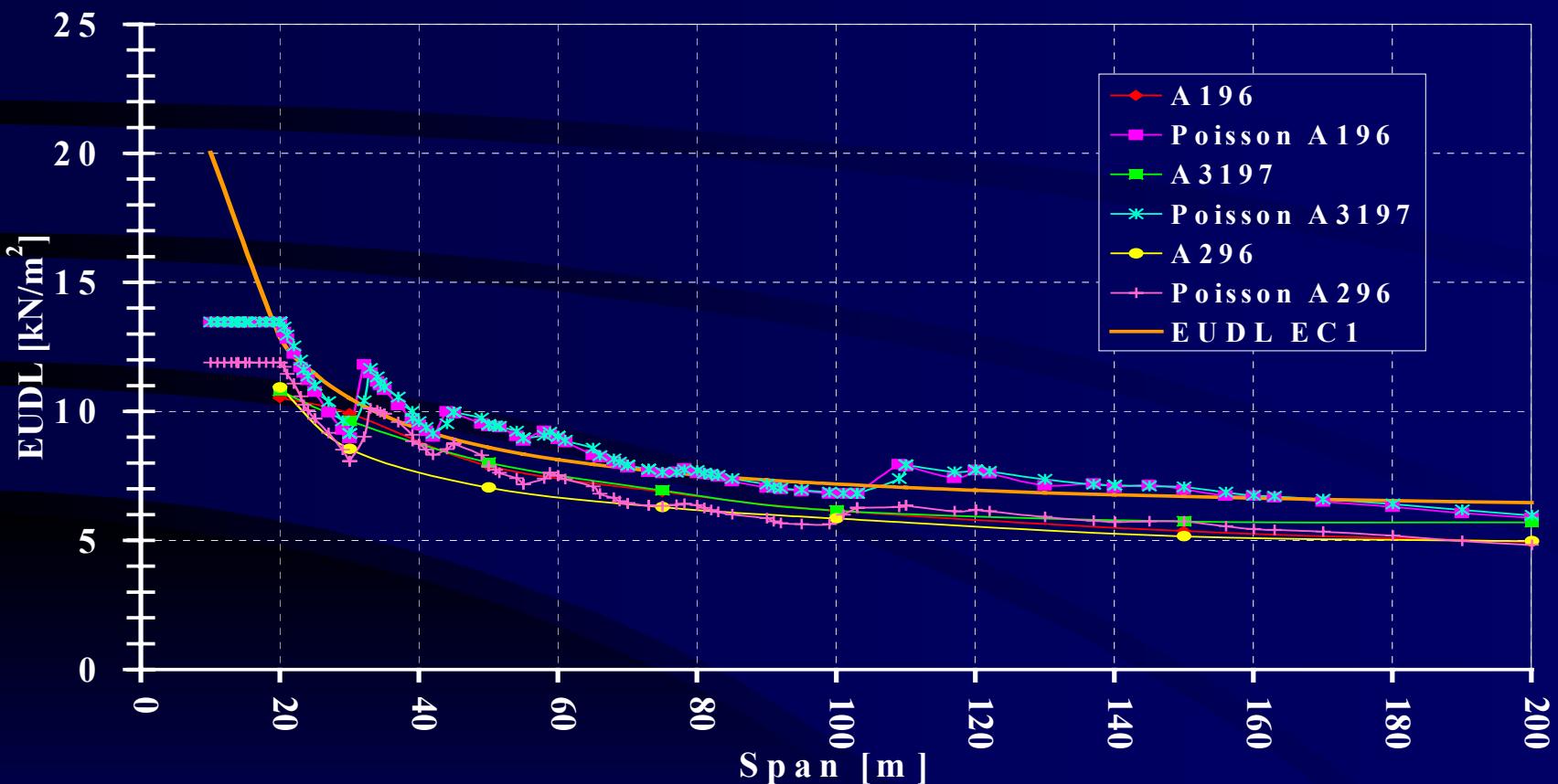
Results: 1 Lane Free Flow



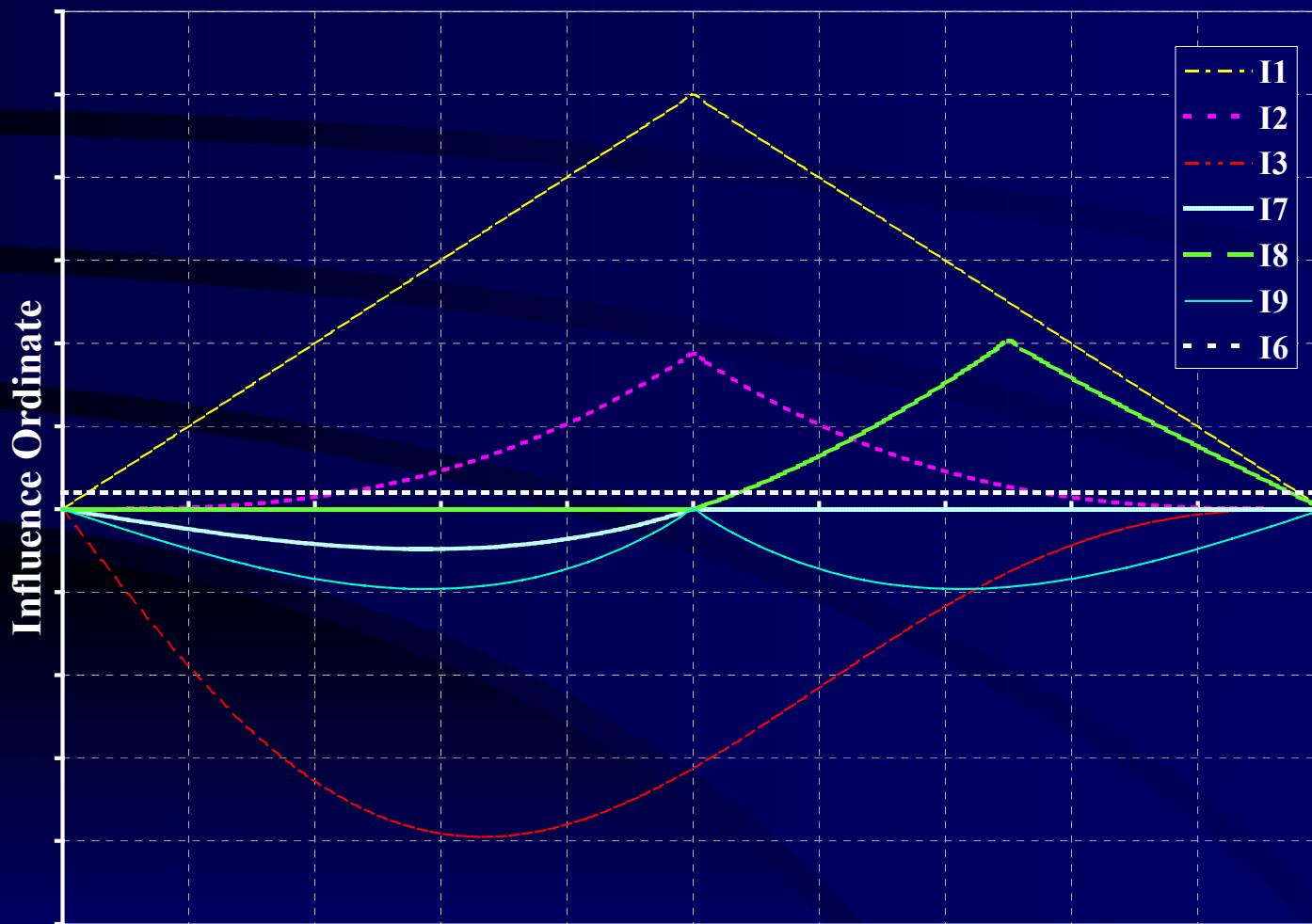
1 Lane Congested



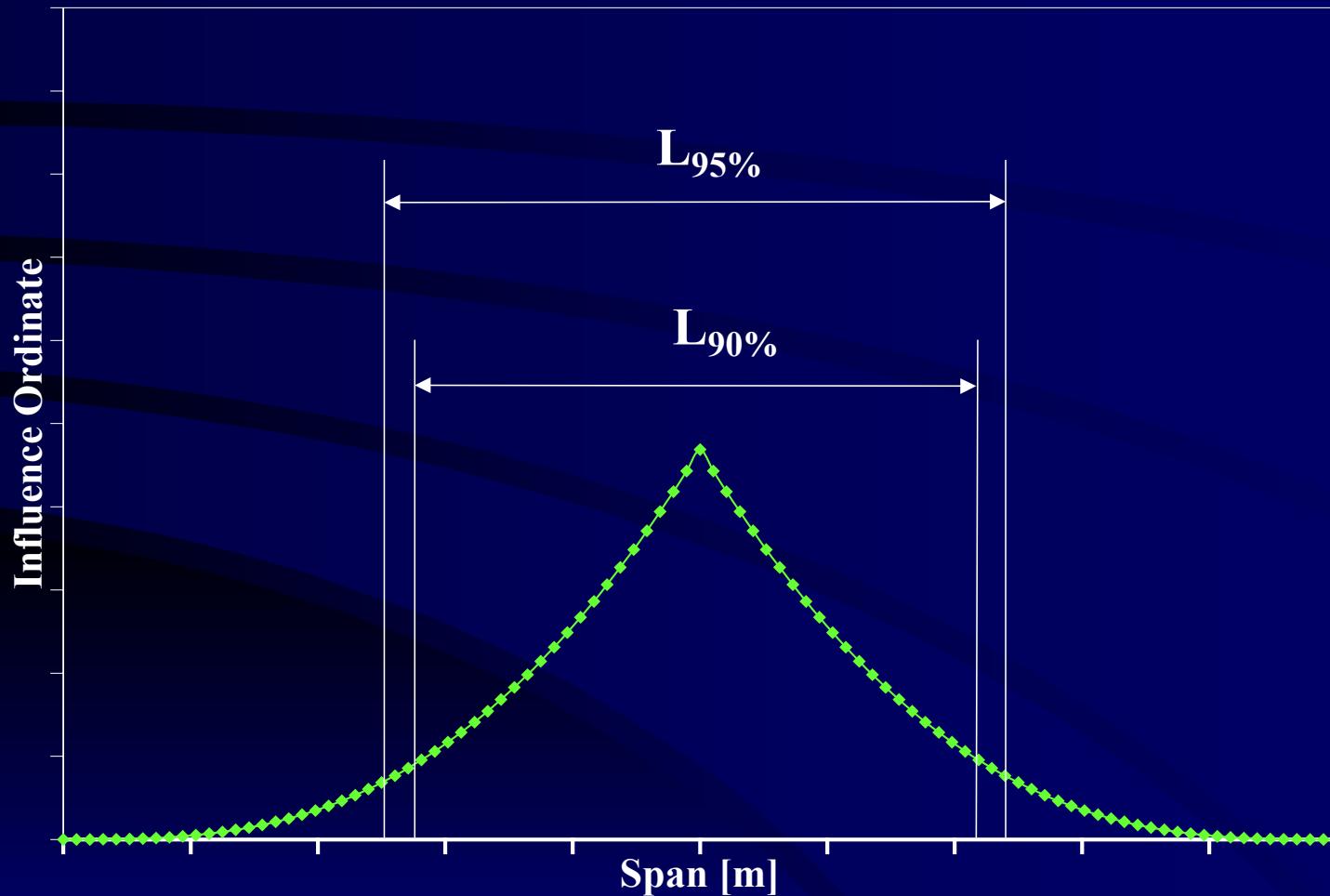
2 Lane Mixed



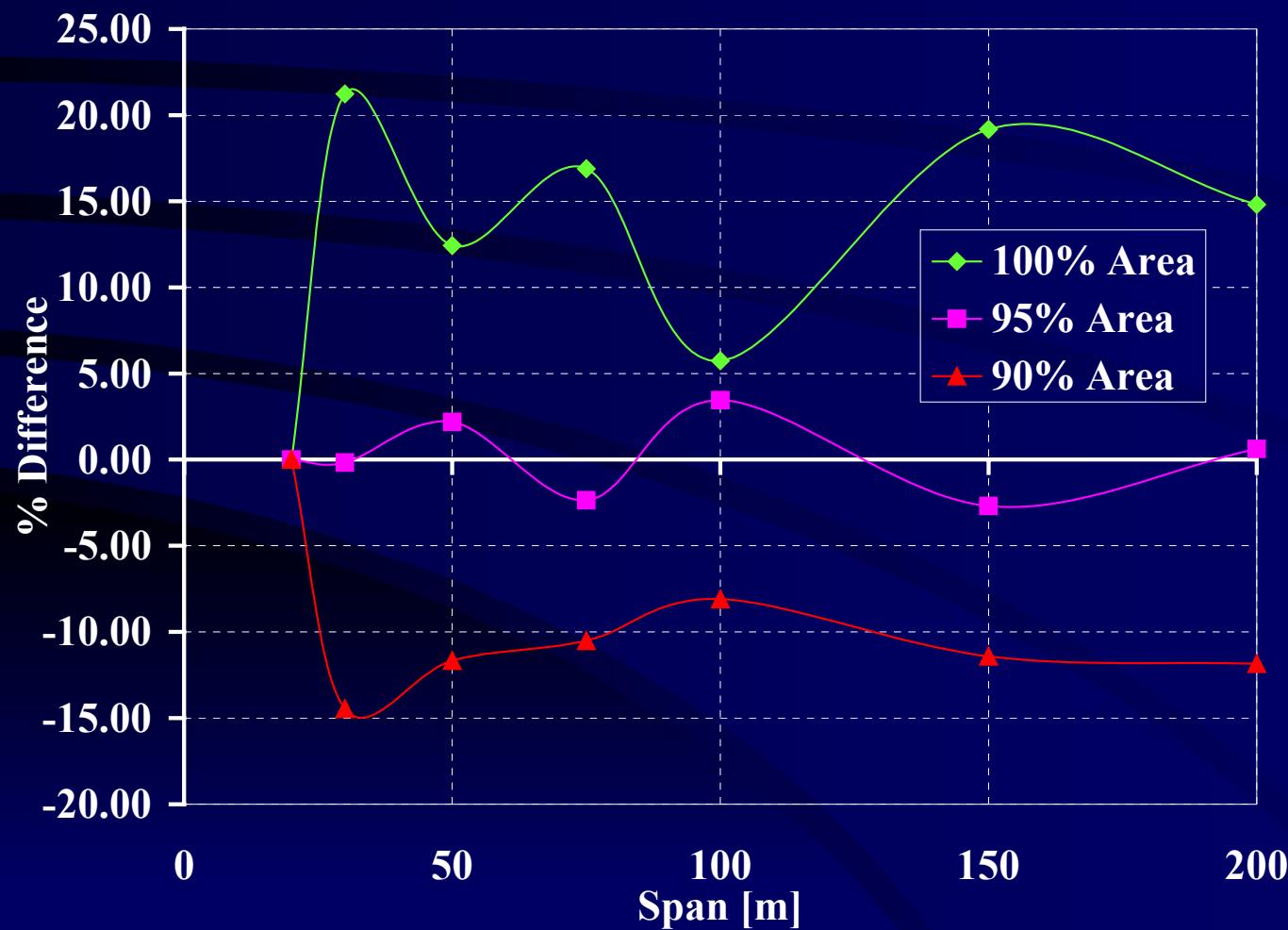
What About Other Load Effects



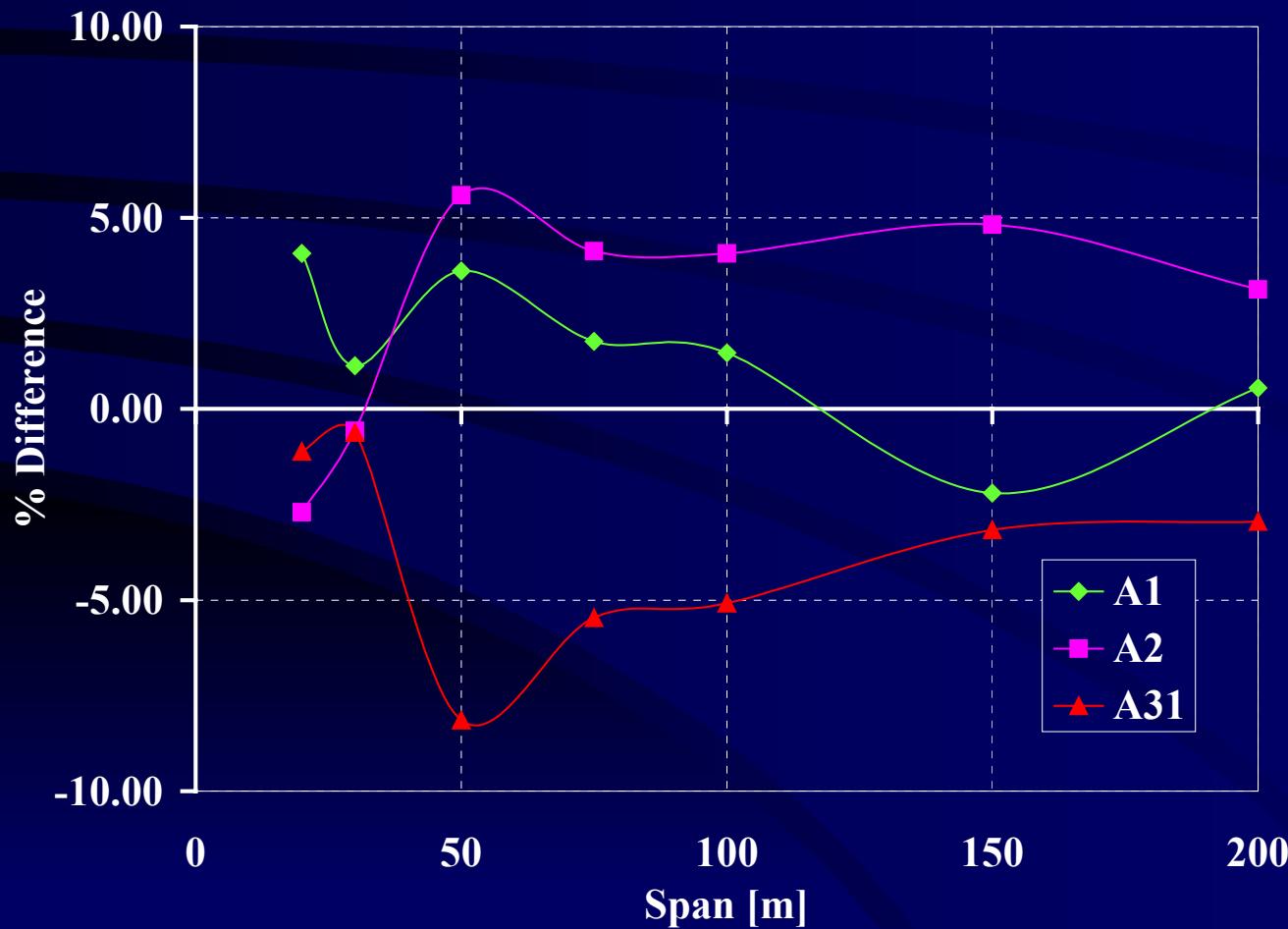
Zone of Significance



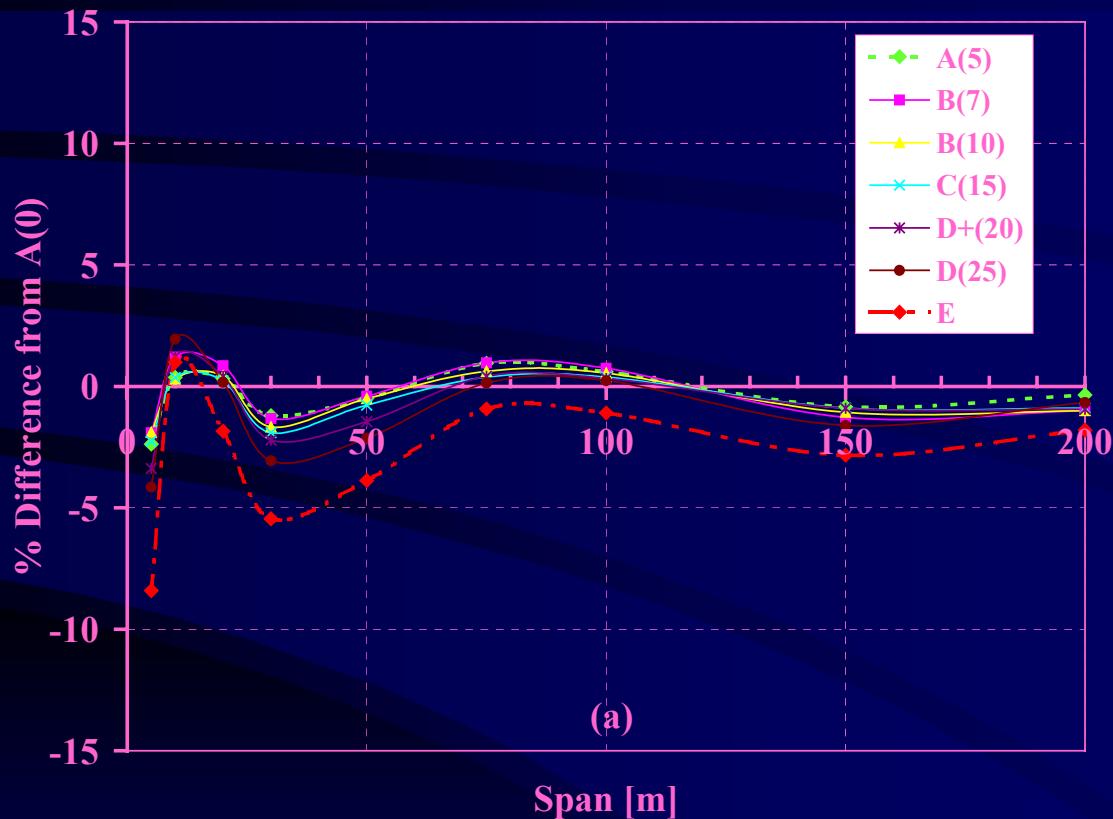
Results: A31, Simply Supported Moment, 1 Lane Free Flow



Results: Simply Supported Moment, 1 Lane Jam Flow

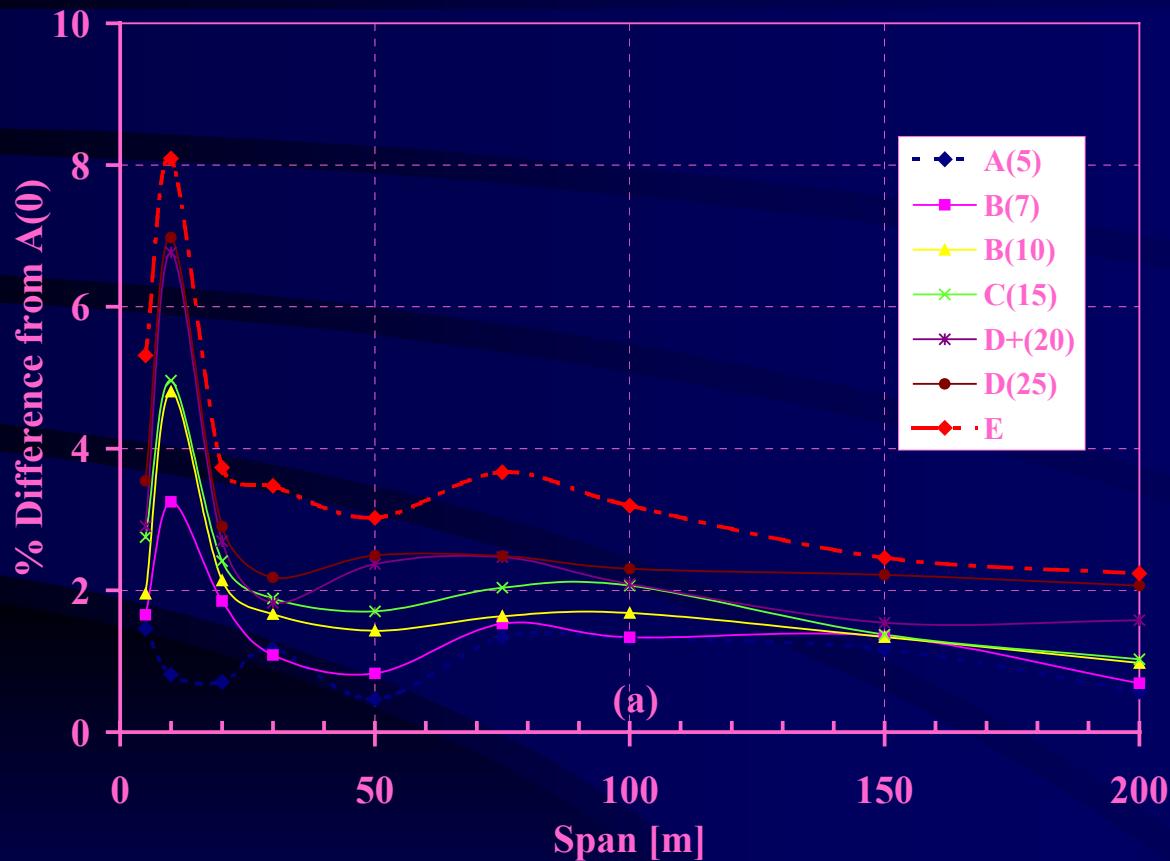


Implication of Data Inaccuracy



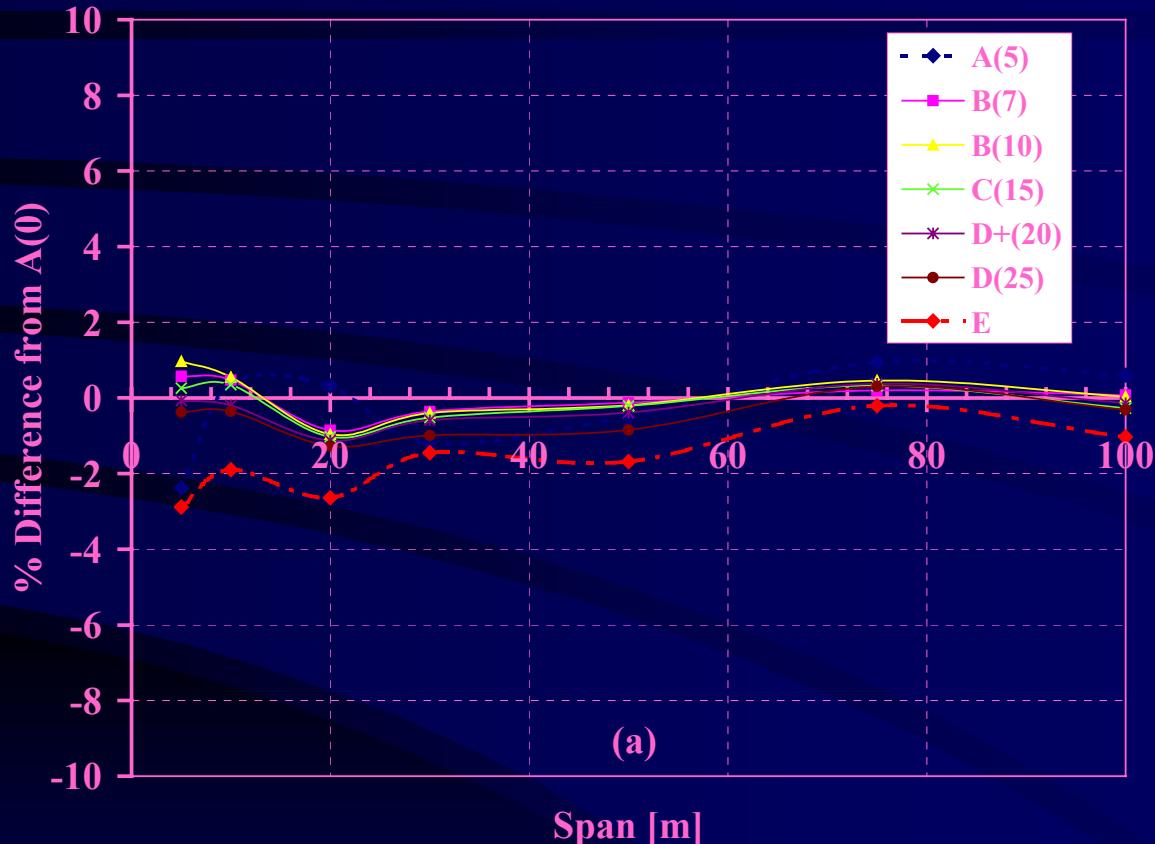
I1-4 Lanes Mixed Flow Mean Error

Implication of Data Inaccuracy



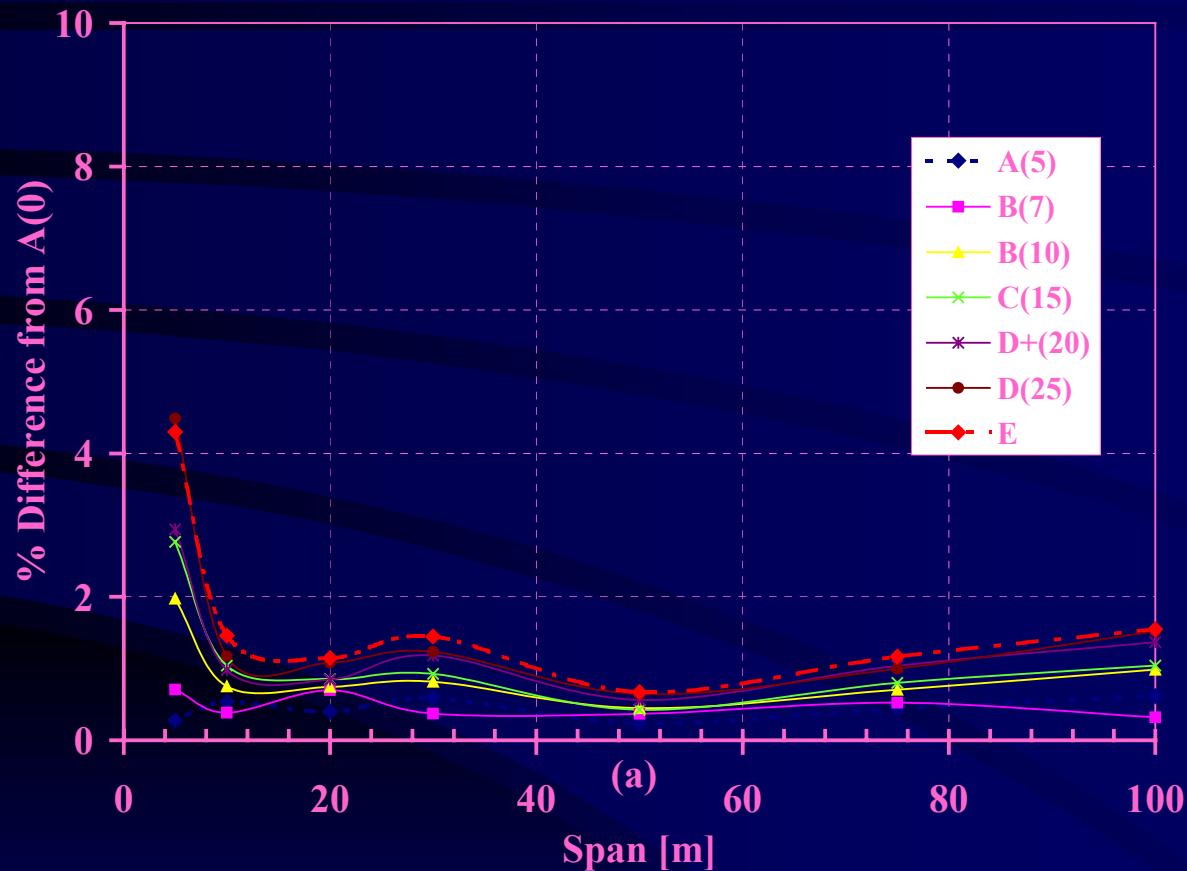
I1-4 Lanes Mixed Flow **Standard Deviation**

Implication of Data Inaccuracy



I9-4 Lanes Mixed Flow Mean Error

Implication of Data Inaccuracy



I9-4 Lanes Mixed Flow **Standard Deviation**

Conclusion

- Development of a stochastic flow model which performs statistical convolution between GVW distribution, likelihood of having n vehicles on the span and knowledge of the shape of the influence surface leads to an analytic expression for the characteristic extreme load effect for bridge code calibration or structural assessment.

Conclusion

- Influence of WIM data inaccuracy function of load effect, span length & quantity of WIM data. Recommended for prediction of characteristic extremes to employ C(15) for span $< 50\text{m}$, less accurate data required for longer spans.

Thank You